CERTAIN MUSCLE PROPERTIES IN RELATION TO DEGREE OF FATNESS AND MUSCLING IN PIG CARCASSES *

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Increasing the lean to fat ratio is a primary objective in swine improvement and selection for this trait has been shown to be effective (e.g. Fredeen, 1971). Although qualitative characteristics of muscle have been the focus of intense research in recent years, the consequences of selection procedures aimed at maximizing lean meat yield remain unresolved. Martin et al. (1971) reporting on certain meat quality parameters for a control population versus lines selected for leanness found line differences to be relatively insignificant. However others (e.g. Weiss et al., 1971a, b) have concluded that selection for a meat-type hog leads to alterations in hormonal and metabolic functions which in turn influence qualitative characteristics. Supporting evidence of relationships between quality/quantity parameters is also provided by various reports indicating that breeds superior in muscling are more prone to produce pale soft exudative (P.S.E.) pork resulting in reduced retail appeal and inferior processing qualities (e.g. MacDougall and Disney, 1967; Hedrick et al., 1968). Nonetheless the hog industry is not likely to compete and prosper without

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continued improvement in carcass merit and the important question to be answered is how far and how fast may we proceed to alter tissue proportions without compromising important muscle properties? Investigation of this question obviously requires examination of various physiological parameters related to growth, and to meat quality.

The present study was conducted to evaluate the interrelationships among variations in carcass fatness and muscling, protein solubility, muscle pH, intramuscular ether extract, color reflectance, tenderness as evaluated by shear value, and finally subjective color-structure and marbling scores.

MATERIALS AND METHODS

146 barrow, 192 gilt and 120 boar carcasses of mixed breeding (Lacombe, Hampshire x L and Poland China x L) were slaughtered at approximately 90 kg liveweight. Hot pH was taken on the kill line after scalding at about 40 minutes post mortem using a probe type electrode inserted into the gracilis muscle. After a 24 hr chill a second pH measurement was taken at the same site. Color-structure scores and marbling scores similar to those described by Forrest et al. (1963) were assigned and carcass measurements were taken. The entire loin section was excised and taken for laboratory dissecting into lean, fat and bone. At 48 hrs post mortem a 300 gm sample of the longissimus dorsi muscle, dissected to eliminate all surrounding tissue and homogenized by repeated grinding through a power

grinder, was analyzed for ether extractable fat, moisture and ash by standard AOAC methods (1960). The ground material was also sampled for water soluble proteins and ultimate pH by the method of Hart (1962).

After dissection a slice about 3 cm thick was cut from the centre of the longissimus dorsi and a probe reading of pH taken. Subsequently the steak was measured for color using a photoelectric color meter* and then cooked in a microwave oven. Cooked steaks were placed in a plastic bag and chilled overnight after which two 2-cm cores were taken for electronic recording of maximum shear values using a Warner-Bratzler shear device.

Standard errors were calculated for each mean. A rapid and robust test of the significance of the difference between any two means is provided by 3 times the greater standard error.

RESULTS

A subjective division between P.S.E. and non-P.S.E. muscle is of necessity arbitrary. However, for purposes of this report the primary criterion used was whether or not "weeping" occurred. Thus subjective color structure scores of 2 or less were classified as mildly (scores 1.5 and 2.0) or extremely (scores 0.5 and 1.0) P.S.E., while scores above 2.5 were considered non-P.S.E. On this basis, 13% of the barrows, 11% of the gilts and 18% of the boars were designated as having P.S.E. properties. Only

* Manufactured by Ernst Schütt Laboratory, Göttingen, Germany.

two of the 458 carcasses were judged to be extreme P.S.E.

Tabulation of the data according to color structure score (Table 1) demonstrated statistically significant differences in post mortem pH, protein solubility, shear values, scores for marbling and color reflectance readings. Increasing values for color structure scores were accompanied by significant increases in pH, marbling score and color and decreasing values in transmission values and shear values. There were no significant differences in carcass leanness between P.S.E. and non-P.S.E. groups of carcasses.

All pH values, % intramuscular fat and subjective quality scores (Table 2) were unrelated to measures of carcass muscling. As carcass muscling increased (or backfat measures decreased), transmission and shear values increased and marbling scores decreased. However measures of carcass muscling had little predictive value for any of these variables. The closest association involved % lean in loin and shear values ($r = 0.30$) indicating that the heavier muscled or leaner carcasses tended to produce tougher pork. However r^2 value for these traits was less than 10%.

Color reflectance was not closely related to other measurements of pork quality (Table 3). Final (48 hr) pH was lowly correlated with initial pH ($r = .36$) and moderately correlated with 24 hr pH ($r = .62$). Final pH and transmission value were quite highly correlated ($r = -.72$) and each was a good predictor of subjective quality score ($r = .61$, $r = -.56$ respectively).

DISCUSSION

The positive association between color-structure scores and pH values observed in this study is in accord with conclusions reached by Topel et al. (1967), Sayre et al. (1964) and Dildey et al. (1970). Although McClain et al. (1969) were unable to detect any difference in ultimate pH for P.S.E. vs normal longissimus dorsi muscle tissue the inverse relationship they reported between transmission value (protein solubility) and P.S.E. score is in agreement with our results and is also in accord with the conclusion of Ockerman and Cahill (1968) and Sybesma and Hart (1965). Penny et al. (1969) found 24-hr pH to have a small but significant influence on water holding capacity. Rapid pH decline at high carcass temperatures is a well established phenomenon of P.S.E. type pork muscle. However results of the present study suggest that the rate of pH decline between 24 and 48 hrs post-mortem is also most extensive in P.S.E. muscle and that ultimate pH (48 hrs post mortem) provides a simpler but equally good objective method for estimating muscle quality ($r = 0.61$) as the more complex procedure of turbidity measurements as suggested by Ockerman and Cahill (1968) ($r = -.56$).

Color reflectance values increased linearly as subjective quality scores increased. However, color reflectance did not provide an adequate method for pork quality evaluation, giving correlations with quality score and pH and % transmission of only .41 and .26 and -.27 respectively. A partial explanation of these low correlations may be provided by the observation by Sayre et al. (1964) that some muscles with low pH and exudative properties do retain a dark color. Topel et al. (1967) also reported that low muscle protein extractability was not entirely consistent with visible P.S.E. muscle characteristics.

Briskey (1964) reported lesser amounts of visible marbling in P.S.E. muscle while Sink et al. (1967) noted no significant differences between P.S.E. and non P.S.E. muscle for total lipid percent. Our results support both of these apparently conflicting reports and we have concluded that, while intrinsic differences in lipid content do not exist between P.S.E. and normal muscle, subjective marbling scores tend to be biased upwards in the presence of the P.S.E. condition. This conclusion is supported by the lack of correlation between transmission values and % intramuscular fat.

Palatability characteristics of P.S.E. muscle have not been clearly established. Briskey (1963) indicated P.S.E. muscle to be less tender than normal muscle. Sayre et al. (1963) found markedly lowered shear values in pork muscle for which pH exceeded 6.0 at onset of rigor mortis and reported high negative correlations between pH readings at four sampling times and shear values. Judge et al. (1960) on the other hand reported a negative correlation between tenderness and degree of muscle firmness. Our data also indicate trends toward lower shear values for darker, higher pH muscle. However, differences in mean shear values among color-structure groups were small and the correlation between pH and shear value was low (-0.24) compared with values $> -.60$ reported by Sayre et al. (1963). Our correlations were however in accord with those reported by Kaufman et al. (1964) and do not indicate major influences on shear values due to degree of visual P.S.E. development. However it is possible that more extreme relationships between pH and shear values would be observed in populations characterized by a higher incidence and more intense development of the P.S.E. condition than was apparent in our data. Indeed, MacDougall and Disney (1967) reported substantially higher shear values for the Pietrain breed which they attributed to faster rates of post-mortem glycolysis.

Extreme muscularity and stress-susceptibility with a consequent high incidence of P.S.E. pork are documented characteristics of the Pietrain breed. This has led to speculation that selection for increased lean content will result in reduced meat quality. Evidence has been presented for breed-based associations between quantity and quality of lean (MacDougall and Disney, 1967; Hedrick et al., 1968) with certain breeds identified as "stress susceptible". Also Dildey et al. (1970) found a correlation of -.73 between color-structure score and % ham and loin, and a similar relationship was reported by Hedrick et al. (1968) when data for several breeds were combined. However these authors found no consistent evidence for this relationship on a within-breed basis. Data from the present study indicated no significant relationships between quality scores and any of the measures of muscling and it would appear that, within a breed, a considerable change in mean carcass muscling and/or fatness will not necessarily entail any meaningful change in quality parameters. On the other hand the contribution of "muscle breeds" in crossbreeding programs should be further investigated.

The present data also indicate that less than 10% of the variation in tenderness is accounted for by variation in muscling and/or fat content. This is in agreement with the conclusions of Skelley and Handlin (1971).

Weiss et al. (1971) suggested that selection for a meat type hog may be expected to influence metabolic and/or hormonal functions. Thus breeds and/or lines within breeds may differ in basic metabolism according to differences in their selection background. That such differences may affect post mortem pH change, and thus carcass "quality" attributes, is suggested by comparing the averages for ultimate pH values of 5.68 and 5.50 reported by Bendall et al. (1966) for large populations of pigs in Britain with the average of 5.75 obtained in the present study. However, the present data suggest that substantial genetic changes in body composition of the pig can be achieved without encountering problems of pork quality.

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Table 1. Pork longissimus dorsi parameters as related to subjective color-structure scores.

	Subjective Quality Score*							
	1 Extreme P.S.E.+	2 Mild P.S.E.	3 Normal Pink	4 Slightly D.F.D.	5 Extreme D.F.D.	1,2 P.S.E.	3,4,5 Non-P.S.E.	Simple Corre-lations
Numbers] Castrates	1	16	76	47	6	17	129	
] Females	1	18	126	44	3	19	173	
] Boars	0	18	65	34	3	18	102	
Hot pH (45 min P.M.)	6.55 (0.05)	6.28 (0.03)	6.48 (0.01)	6.55 (0.02)	6.78 (0.04)	6.29 (0.03)	6.51 (0.01)	.36
24 hr pH	5.70 (0.20)	5.82 (0.04)	5.89 (0.02)	6.09 (0.40)	6.64 (0.13)	5.81 (0.04)	5.98 (0.02)	.43
48 hr pH	5.35 (0.25)	5.55 (0.03)	5.68 (0.01)	5.92 (0.03)	6.53 (0.09)	5.54 (0.03)	5.78 (0.01)	.61
% transmission	96.5 (1.5)	88.0 (2.4)	64.4 (1.7)	40.8 (2.6)	16.5 (6.4)	88.3 (2.3)	55.7 (1.5)	-.56
Marbling score	2.0 (0.20)	2.52 (0.15)	3.52 (0.07)	4.21 (0.11)	4.42 (0.61)	2.50 (0.14)	3.76 (0.06)	.39
% Intramuscular fat	2.12 (0.62)	1.89 (0.09)	2.00 (0.04)	1.95 (0.06)	1.71 (0.15)	1.90 (0.08)	1.98 (0.03)	-.05
Color reflectance	52.0 (4.0)	63.3 (0.85)	66.1 (0.32)	69.1 (0.58)	74.9 (2.29)	62.9 (0.87)	67.3 (0.31)	.41
Loin area sq cm	34.2 (4.51)	30.0 (0.52)	29.3 (0.19)	29.1 (0.32)	29.5 (0.84)	30.2 (0.52)	29.3 (0.19)	-.08
Maximum shoulder fat cm	3.12 (0.07)	3.20 (0.07)	3.38 (0.03)	3.38 (0.05)	3.30 (0.04)	3.20 (0.07)	3.38 (0.03)	.06
% lean in loin	43.4 (3.87)	42.9 (0.68)	41.2 (0.29)	41.5 (0.48)	40.9 (1.54)	42.9 (0.66)	41.3 (0.25)	-.06
% fat in loin	41.0 (2.78)	41.3 (0.82)	43.1 (0.36)	42.8 (0.60)	43.2 (2.13)	41.2 (0.79)	43.0 (0.31)	-.02
Shear value	53.0 (4.0)	46.4 (1.6)	43.5 (0.6)	44.8 (1.2)	40.0 (4.5)	46.6 (1.6)	43.7 (0.6)	-.07

* Standard errors in brackets + Pale soft exudative [illegible]

Table 2. Various pork quality parameters as related to measures of carcass leanness and muscling.

Mean		Maximum Shoulder Fat cm 3.0	3.5	4.0	Simple Correlation	% Dissectible Lean in Loin * 34	42	50	Simple Correlation
Numbers	] Castrates	19	79	39		46	99	1	
	] Females	54	120	13		9	156	24	
	] Boars	72	39	7		6	75	39	
Hot pH		6.47 (0.02)	6.48 (0.01)	6.52 (0.03)	.01	6.52 (0.03)	6.49 (0.02)	6.45 (0.03)	-.08
24 hr pH		5.94 (0.03)	5.92 (0.03)	6.11 (0.06)	.13	6.16 (0.06)	5.92 (0.02)	5.93 (0.04)	-.15
Final pH		5.73 (0.02)	5.72 (0.02)	5.89 (0.05)	.12	5.93 (0.05)	5.72 (0.01)	5.75 (0.04)	-.18
% transmission		65.2 (2.62)	59.6 (1.96)	46.5 (4.22)	-.17	39.4 (3.76)	62.7 (1.65)	63.2 (4.25)	.21
Color reflectance		68.1 (0.52)	66.4 (0.41)	65.6 (0.76)	-.15	65.1 (0.84)	66.7 (0.34)	68.6 (0.92)	.22
Shear value		47.5 (0.98)	43.5 (0.70)	38.1 (1.11)	-.28	39.4	43.9	49.2	.30
Marbling score		3.44 (0.12)	3.63 (0.08)	3.75 (0.19)	.10	3.93 (0.19)	3.64 (0.07)	3.18 (0.17)	-.18
Quality score		5.85 (0.12)	5.83 (0.08)	6.02 (0.15)	.06	6.16 (0.18)	5.80 (0.06)	5.94 (0.21)	-.06
% ether extract		2.01 (0.06)	1.93 (0.04)	2.05 (0.09)	.01	2.00 (0.09)	1.98 (0.04)	1.82 (0.07)	-.01

* Standard errors in brackets

Table 3. Simple correlations among pork muscle attributes.

	Final pH	% transmission	Color reflectance
Final pH			
% transmission	-.72		
Color reflectance	.37	-.27	
Hot pH	.36	-.43	.25
24 hr pH	.62	-.54	.26
% intramuscular fat	.01	.04	-.17
Maximum shoulder fat	.12	-.17	-.03
% dissectible lean in loin	-.18	.21	-.14
Shear value	-.24	.20	.03
Subjective score	.61	-.56	.41

N = 454